Exemption No. 8160

UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
RENTON, WASHINGTON 98055-4056

In the matter of the petition of **EMBRAER Empresa Brasileira de Aeronáutica S/A** Section 25.841(a)(2)(ii), Amendment 25-87 of Title 14, Code of Federal Regulations	**Regulatory Docket No. FAA-2002-14013**

GRANT OF EXEMPTION

By letter dated December 4, 2002 (GEC-4289/2002), Mr. Paulo C. Olenscki, Certification Manager, EMBRAER Empresa Brasileira de Aeronáutica S.A., Av. Brigadeiro Faria Lima 2170, 12227-901 – São José Dos Campos, SP, Brazil, petitioned for an exemption from the requirements of § 25.841(a)(2)(ii), Amendment 25-87 of Title 14, Code of Federal Regulations (14 CFR), to permit EMBRAER, for the Model ERJ-170 series airplanes, to be relieved of the requirement that the airplane cabin altitude during a decompression be limited to 40,000 feet for any duration.

Sections of the Federal Aviation Regulations (FAR) affected:

> Section 25.841(a)(2)(ii), at Amendment 25-87, requires that the airplane must be designed so that occupants will not be exposed to a cabin pressure altitude that exceeds 40,000 feet after decompression from any failure condition not shown to be extremely improbable.

The petitioner's supportive information is as follows:

EMBRAER's supportive information is summarized as follows.

Embraer explained that there have been difficulties meeting this requirement for the new Model ERJ-170 series airplanes. They noted that the FAA has tasked an Aviation Rulemaking Advisory Committee (ARAC) Harmonization Working Group to review this regulation; that group is scheduled to deliver its recommendation to the FAA in a matter of months. Meanwhile, the FAA has prepared a draft interim policy that describes the method it will use to consider petitions for exemptions. Embraer prepared its petition based, in part, upon the material presented in that interim policy.

Embraer expressed the view that should the current regulation remain in its present form and the FAA not grant its petition, the new ERJ-170 series airplanes would be unable to operate competitively and economically with existing airplane fleets in US airspace. In order to comply with the rule as written, the new airplanes will have to limit their maximum operating altitude to 40,000 feet or for operation rules, FL 390 (flight level 39,000 feet). This would negatively affect safety by forcing operation of most new airplanes into more congested airspace in the US.

By contrast, current JAA regulations would enable the ERJ-170 series airplanes to fly up to a ceiling of 41,000 feet without any operational restrictions in European Community airspace.

Embraer stated that its design process took § 25.841(a), at Amendment 25-87, into consideration. In addition, Embraer has taken Advisory Circular (AC) 25-20 into account in its analysis of cabin decompression. A copy of that analysis (EMBRAER Report 170PRA001) has been provided to the FAA. The report analyzes decompression due to engine rotor burst; a cabin pressure control system malfunction; wheel rim release; tire burst; hydraulic system failure; toilet vacuum system malfunction; structural fatigue damage; and failure of a window, windshield, door, or antenna. The Embraer Model ERJ-170 series airplane complies with all of § 25.841 at Amendment 25-87, except for certain uncontained engine failures.

Embraer suggests that operation above 40,000-foot cruise altitude would enhance safety, since previously certified large transport aircraft which incorporate established design practices have operated at altitudes in excess of 40,000 feet for more than 20 years. Historically, relatively few accidents or incidents have occurred due to rotor burst during cruise. Statistics from the worldwide commercial fleet reveal that less than 7 percent of the fatalities have occurred during cruise, even though the highest percentage of flight time is at cruise.

Embraer stated that very few decompression incidents, if any, have exposed an airplane cabin to pressure altitude profiles that have caused injury to passengers. Industry history reveals that few cases of catastrophic decompressions at high altitude have occurred and that those which have occurred have typically involved small business jets. Embraer noted that the FAA has cited few cases of rotor burst in cruise. In one such instance, a DC-10 crossing New Mexico reported several cases of initial decompression sickness, apparently with no permanent injuries. Embraer added that the rotor burst in that case was believed to have been caused by crew action.

Embraer stressed that the discrepancy that currently exists between the JAA's and the FAA's interpretation of the applicable rules is due to differing positions regarding the physiological limits criteria and the 1/3 rotor disk model for uncontained engine failures which is used to determine fuselage hole size.

Embraer explained that the FAA assigned an ARAC Harmonization Working Group the task of addressing concerns raised by the regulation and of reaching a consensus among medical experts from the FAA, the JAA, and various industry groups. Additional work remains before that consensus is achieved.

Embraer noted that while awaiting the results of this report, the FAA issued a draft interim policy to address this issue because of the demands of industry and the need to provide additional guidance on an alternate acceptable means of compliance for the certification of new airplanes until the ARAC process is completed. According to the FAA's Draft Interim Policy, in order for the industry to certify airplanes for a ceiling of 41,000 feet, an exemption must be obtained which includes the requirements contained in FAR sections 25.841(a)2(i) and (a)2(ii).

Embraer notes that 14 CFR 25.841(a)(3) specifies that engine failures are to be considered in showing compliance. The company provided the results of its analysis of cabin decompression in which it considered all engine failures. The analysis indicated that only one particular rare event—an uncontained engine rotor burst—may prevent flight above 40,000 feet up to the maximum ceiling of 41,000 feet for the ERJ-170 series airplanes. Embraer added that there is insufficient data on engine rotor burst for the modern engines in new airplanes.

Embraer's analysis suggested that, for second-generation engines, the likelihood of an uncontained engine failure with resultant fuselage strike was on the order of 1.5 E-9 per flight hour.

Embraer provided a list of reference research papers on physiological limits to occupants following cabin decompression. The company's conclusion, based on review of these papers, was that the physiological limits are not significantly affected, whether cabin decompression occurs at 40,000 feet or 41,000 feet. A listing of the specific papers and a summary of each are included in Embraer's petition, dated December 4, 2002, available in the Docket Mangement System on the Internet at dms.dot.gov; the docket number is FAA-2002-14013-1.

Embraer noted that the FAA's draft interim policy utilized the alveolar partial pressure of oxygen time integral method to assess physiological risk to the occupants. The company stated that FAA proposed that exposure to high altitudes be kept to values such that a resulting pressure-time integral of the difference in the calculated mean alveolar partial pressure of oxygen to the reference condition (mean alveolar partial pressure of oxygen at 30,000 ft) was less than the critical value given in the draft policy. In order to generate the integration, a correlation between cabin pressure and alveolar partial pressure is required.

Embraer noted that according to USAF Flight Surgeon's guide, for the unacclimatized person, an alveolar oxygen tension of less than 50 mmHg is considered as approaching a severe state of hypoxia, and an oxygen tension of 30 mmHg is not adequate for supporting consciousness; thus, collapse is imminent. While the effects of alveolar oxygen partial pressures below 25,000 feet have been well documented, according to Embraer, the effects of pressures above 25,000 feet is the subject of debate within the medical community.

Embraer used a relationship between total atmospheric pressure and alveolar partial pressure of oxygen to make certain calculations. This relationship was based upon a theoretically derived value. The value assumed that at a barometric pressure of 87 mmHg (50,000 feet) with a normal carbon dioxide tension in the lungs of 40 mmHg and a normal water vapor tension of 47 mmHg—even when breathing pure oxygen—alveolar oxygen tension is reduced to zero and approaches a true state of anoxia. Embraer suggested that, while this outcome is the subject of debate, the methodology is conservative in that the true level of alveolar partial pressure of oxygen in the average person will be above zero at an altitude of 50,000 feet.

Embraer considered that—if the most conservative approach for extrapolation with 0 mmHg alveolar partial pressure at 50,000 feet is applied to experiments performed by J.B. Brierley, A. N. Nicholson and J.R. Ernsting in the late 1960´s and if the differences between primate and human physiology are considered—values less than 3,000 mmHg-seconds indicate adequate protection to the occupants in the rare event of sudden decompression.

Embraer calculated the cabin altitude and airplane altitude resulting from an uncontained engine failure. They then used the relationship between atmospheric total pressure and mean alveolar partial pressure of oxygen to calculate the alveolar partial pressure of oxygen integral for the resulting decompression event. In all cases, the value was below the 3,000 mmHg-seconds criterion.

Embraer noted the results of their wind tunnel tests and used a conservative emergency descent rate (6,500 feet per minute). The company stated that an improved airplane descent rate of 9,600 feet per minute could be substantiated based upon the wind tunnel data.

Embraer provided information on the likelihood of an uncontained engine failure at high altitude. Embraer's research yielded the following information:

1) There have been six known cases of disk or spacer departure in cruise in the industry-wide high bypass turbofan fleet. All six were all on first-generation high bypass engines, i.e., on 747, L1011 or DC10 airplanes.

2) According to data provided by the Boeing Company, the 747, L1011, and DC10 airplanes have accrued 81 million flight-hours (287 million engine hours) to date. Approximately 70% of the flight-hours have been spent in cruise. (For this fleet, the mean flight duration is 3.5 hours.)

3) The rate of disk burst in cruise in first generation high bypass airplanes is, therefore, 1E-7 per airplane hour or 3E-8 per engine hour.

4) The second-generation fleet has a rate of uncontained failure which is much lower than that of the first generation fleet. Considering all engine fragment types together, the rate of release for second-generation engines is only 23% of that for first generation engines.

5) Applying the ratio of 23% to the first generation cruise disk burst rate results in an estimated second generation cruise disk burst rate of 7E-9/engine hour.

6) The risk of rotor burst for two engines in cruise is 1.4E-8 per flight hour.

Embraer noted that in their analysis of cabin decompression due to rotor burst, they considered all possible pressure vessel structural damages, taking into consideration engine and auxiliary power unit (APU) debris models and spread and risk angles. A table presented the most critical pressurized cabin structural damage possibilities, describing the size of the damage and the spread and risk angles for which these damages occur. Sketches showed the damage and defined the hole sizes and areas. (Embraer Report 170-PRA001).

The methodology and assumptions defined in AC 20-128A were used to perform the analysis.

According to Report 170-PRA001, the risk of a fuselage strike hit by uncontained rotor of second-generation engines is in the order of 1.5 E-09 per flight hour. The event is not extremely improbable; however, for the new generation engine, there is clear indication that a rotor burst threat will be an extremely improbable event in the near future.

Embraer conducted further research regarding the aerodynamic performance capabilities of flight control surfaces to improve the emergency descent. Analysis demonstrated that when using updated wind tunnel data and employing 30 degrees of flight spoilers, the airplane could descend from 41,000 feet to 25,000 feet in 2 minutes (taking into consideration 20 seconds for pilot reaction time and initiation of descent).

Further, research revealed that following a one-engine rotor burst and the resulting loss of thrust, the airplane starts to descend between periods of pilot recognition time. Once the pilot recognizes the failure, the aircraft is at an altitude of approximately 40,000 feet.

Embraer noted that another safety factor is the pilot recognition time of 20 seconds. They noted that there is a consensus in the ARAC Harmonization Working Group that the time needed to recognize the failure and initiate descent is 17 seconds. The Model ERJ-170 series airplanes provide a margin of 3 seconds, according to Embraer's decompression analysis.

Embraer provided airplane altitude-time history and cabin pressure-time history plots and information on the other failure scenarios and the associated rates of descent to 25,000 feet and to 10,000 feet.

Embraer noted that its threat minimization effort included a pressure demand mask for the pilots and that three design features had been adopted to enhance survivability of an uncontained engine rotor burst. These features are (1) wiring duplication and separation of the passenger oxygen masks, (2) wiring duplication between cabin pressure controllers and Outflow Valve, and (3) wiring duplication and separation for the spoiler actuation.

Public Interest

The Model ERJ-170 series airplanes fully comply with § 25.841(a), Amendment 25-87, except in regard to the narrow exemption which Embraer has requested. All possible threat minimizations for cabin occupants have been taken into consideration. The new airplanes, therefore, offer a significantly higher level of safety than do transport category airplanes previously certified.

As previously discussed, the likelihood of a sudden decompression from all possible failure modes should be less with the Model ERJ-170 series airplanes than with existing transport airplanes in the fleet. The narrow exemption requested will not adversely affect safety.

Authorization for flight at 41,000 feet (Flight Level or FL 410) will enable the new airplanes to fly at FL410, creating an additional line of airplane separation in US airspace without adversely affecting passenger safety. In addition, authorization for flight at 41,000 feet will enable the Model ERJ-170 series airplanes to compete fairly with existing airplanes subject to older amendments without causing any adverse effects. Lastly, the public interest will be served by the use of the new generation of engines in the market, because they offer better fuel efficiency, thus
lower operational cost.

Level of Safety Provided

As previously noted, 14 CFR 25.841(a)(2)(ii), at Amendment 25-87, is being studied by an ARAC group which is scheduled to deliver its recommendation to the FAA in November, 2003. The FAA has prepared a draft interim policy which describes the method that it will use to consider specific requests for exemptions. This method relies upon quantitative and qualitative means to analyze the relative risk to the occupants in the event of a decompression. The method ensures that as airplane cruise altitude is increased, the airplane manufacturer has incorporated design features commensurate with the increased risk.

Section 25.841(a)(2)(ii), at Amendment 25-87, requires that the airplane be designed so that occupants will not be exposed to a cabin pressure altitude that exceeds 40,000 feet after decompression from any failure condition not shown to be extremely improbable. The FAA has always stressed the need for consideration of specific threats, regardless of their probability of occurrence. The intent of the regulation was to ensure that the cabin environment would be sufficient to prevent loss of life or brain damage for all occupants, even those unable to don oxygen masks. Preliminary results from the ARAC working group, however, indicate that certain occupants—especially the elderly, young children, and those suffering from specific medical conditions—are at some risk in the event of decompression.

The FAA reviewed the information provided by Embraer and concluded that the increased risk associated with the excursion above 40,000 feet was minimal and was within the uncertainty level of the available physiological data.

Summary for Federal Register

Embraer is requesting relief from the requirements of 14 CFR 25.841(a)(2)(ii), as amended by Amendment 25-87, which specifies that the airplane must be designed so that occupants will not be exposed to a cabin pressure altitude that exceeds 40,000 feet after decompression from any failure condition not shown to be extremely improbable. The petitioner requests that the cabin air pressure limit be equivalent to 41,000 feet altitude for the Model ERJ-170 series airplanes following an uncontained engine rotor burst hitting the pressurized cabin.

Notice and Public Procedure Provided

On March 31, 2003, the FAA published notice of the petition for exemption in the Federal Register and requested comments from the public. No comments were received.

FAA's Analysis of the Petition

The petitioner is requesting relief from the regulation that limits the cabin pressure altitude to a maximum of 40,000 feet, so that the Model ERJ-170 series airplanes may operate up to 41,000 feet. This altitude represents approximately a 5% excursion in the cabin pressure altitude limit allowed by the current airworthiness standards.

The petitioner provided several arguments in its petition. The petitioner and the FAA have exchanged correspondence on the design features and airplane performance capability. The FAA has determined that these arguments provide sufficient justification for granting an exemption.

This determination is based mainly on a review of material obtained during the deliberations of the previously mentioned ARAC rulemaking activity on this subject. The ERJ-170 series airplane is capable of descending rapidly from an altitude of 41,000 feet to an altitude below 25,000 feet. The slight excursion in cabin altitude above 40,000 feet is within the uncertainty band of available physiological data.

The compelling arguments made by the applicant included the calculation of an alveolar partial pressure of oxygen time integral (pAO2-time integral), discussion of the results of available flight physiology research, and the mitigating design and operational features of this airplane.

The petitioner utilized the same relationship between cabin pressure and alveolar partial pressure of oxygen that the FAA proposed in the interim policy memorandum on this subject, which the FAA believes to be “conservative” in the sense that the actual level of alveolar partial pressure of oxygen in the lungs would be higher than indicated by the relationship. The petitioner showed that for all of the failures modes reviewed the resultant pAO_2-time integral levels were less than the critical value selected by the FAA.

The petitioner also provided data on the likelihood of occurrence of the worst-case failure (i.e., uncontained engine rotor failure). While the FAA concurs with the petitioner that uncontained engine failures are rare events, this consideration did not have a major bearing on the granting of the exemption.

FAA believes that ultimately, occupant survival during a decompression event depends upon a swift descent to a lower altitude. The FAA reviewed the petitioner’s airplane descent profile and noted that the petitioner used a conservative value for the rate of descent, even though the petitioner had data—from wind-tunnel tests—showing that the maximum descent speed was greater. Furthermore, FAA noted that, realistically, the maximum cabin pressure excursion above 40,000 feet pressure altitude resulting from an uncontained engine failure was approximately 1%, taking into account design and operational considerations.

The grant of this exemption has the potential for reducing operators’ costs, thereby benefiting the traveling public while also providing increased flexibility to the manufacturer.

The Grant of Exemption

In consideration of the foregoing, I find that a grant of exemption is in the public interest and will not adversely affect the level of safety provided by the regulations. Therefore, pursuant to the authority contained in 49 U.S.C. 40113 and 44701, delegated to me by the Administrator, the petition of EMBRAER Empresa Brasileira de Aeronáutica S/A, for an exemption from the requirement of 14 CFR 25.841(a)(2)(ii), as amended by Amendment 25-87, is hereby granted. This exemption specifies that, in the event of decompression following an uncontained engine rotor burst hitting the pressurized cabin, the cabin pressure altitude in the ERJ-170 series airplanes may reach but not exceed 41,000 feet. The exemption is subject to the condition that the Airplane Flight Manual state that the maximum operating pressure altitude is 41,000 feet.

Issued in Renton, Washington, on October 24, 2003.

/s/ Vi L. Lipski
Manager
Transport Airplane Directorate
Aircraft Certification Service

Regulatory Docket No. FAA-2002-14013

REFERENCES

1. "Factors Influencing the Time of Safe Unconsciousness (TSU) for Commercial Jet Passengers Following Cabin Decompression", James G. Gaume, Aerospace Medicine, April, 1970.

2. "Neurological Study of Simulated Decompression in Supersonic Transport Aircraft", Aerospace Medicine, J.B. Brierley and A. N. Nicholson, August 1969.

3. "Neurological Sequelae of Prolonged Decompression", Aerospace Medicine, A.N. Nicholson and J.R. Ernsting, April 1967.

4. "An Analysis of the Oxygen Protection Problem at Flight Altitudes Between 40,000 and 50,000 Feet, Final Report", prepared for the Federal Aviation Agency, Contract FA-955, by Blockley and Hanifan, February 20, 1961.

cc: ANM-111, ANM-112, ANM-113, ANM-115, ANM-116, ANM-117

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